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EVALUATION OF INNOVATIVE PAINTING PROCESSES

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13. ABSTRACT *(Maximum 200 words)*
This report details an evaluation of two novel spray painting techniques that may decrease volatile organic compound (VOC) emissions associated with application of surface coatings. One technique uses supercritical carbon dioxide as a solvent and a propellant to deliver and disperse the coating. The second system, called the Ultra-Low Volume (ULV) process utilizes pressurized nitrogen to deliver a constant-flow, very soft spray through the gun nozzle. The CO_2 system encountered problems in delivering urethane topcoats and was eliminated from field testing. Data were gathered on VOC emissions, paint consumption, coat thickness, and workplace exposure during application of an epoxy primer and a silica-filled chemical resistant (CARC) topcoat to a fleet of trucks at Warner Robins AFB GA. The ULV process was compared to a conventional air atomizing gun system. Results revealed a 50-percent decrease in VOC emissions, and a 30-percent decrease in paint consumption at no increase in exposure when using the ULV system.

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PREFACE

This report was prepared by Pandalai Coating Company, 837 Sixth Avenue, Brackenridge PA 15014, under contract #68D00088 for the U.S. Environmental Protection Agency (EPA) Air and Energy Engineering Research Laboratory (AEERL), Research Triangle Park NC 27711, and the Civil Engineering Laboratory (CEL), Air Force Engineering Support Agency, 139 Barnes Drive Tyndall AFB FL 32403-5319.

This technical report summarizes work done between 15 October 1990 and 15 October 1991. The EPA program monitors were Charles H. Darvin and Bobby E. Daniel; the CEL project officer was Dr. Joseph D. Wander.

Generous cooperation by BASF personnel in Atlanta GA, Air Force personnel at Wright Laboratories and Warner Robins Air Logistics Center, David F. Pulley of the Naval Air Development Center (NADC) in Warmister PA, and Lyndon S. Cox an EPA Senior Environmental Employee is gratefully acknowledged.

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EXECUTIVE SUMMARY

OBJECTIVE: The objective of the project was to perform a practical evaluation of two innovative spray painting technologies that can decrease volatile organic compound (VOC) emissions associated with application of surface coatings.

BACKGROUND: Solvents added to decrease the viscosity of coatings to levels compatible with application methods are a major source of volatile organic compounds (VOCs). These VOCs are subject to regulation under environmental codes, including Title 3 of the Clean Air Act Amendments. While end-of-pipe technology exists to capture or destroy these volatiles from the spray booth emissions air stream, it is expensive to maintain and operate. A desirable alternative, when practical, is to lower the solvent content (i.e., raise the solids content) of the coating as applied. Practicality depends on the availability of a delivery system that can apply a high-solids coating formulation at the viscosity supplied. This approach, defined as pollution prevention, lowers the amount of solvent available for emission to the atmosphere.

This study initially addressed two approaches to spraying high-viscosity coatings. Unicarb technology uses supercritical carbon dioxide, a relatively nontoxic, nonpolluting material, as both a solvent to adjust viscosity and as the propellant to deliver and disperse the paint. The embodiment of this technology at the time of this study proved incompatible with current two-component urethane topcoat formulations, and thus was not evaluated in the field. However the principle remains valid, and reexamination of Unicarb process as a means of applying urethane topcoats can be reexamined when the process and coating are compatible.

The second approach is a low-tech device employing a portable pressure cell comprising two connected chambers, one pressurized with nitrogen gas, and the second isolated from the first by a floating piston that transmits the gas pressure to a charge of paint. Flow of paint from the second chamber through a nozzle results in a constant-flow, very soft delivery of a paint spray. This technology, now called the Ultra-Low Volume (ULV) spray process, is available from commercial outlets under license from Air Compliance Technologies.

SCOPE: During the course of this study, the ULV gun was qualified to apply MIL-C-83286 and MIL-C-85285 urethane topcoats, and was subsequently used in the field to apply MIL-P-23377 epoxy primer and a silica filled chemical agent resistant (CARC) topcoat, MIL-C-53039. Data were gathered on VOC emissions, paint consumption, coat thickness, and workplace exposure during application of prime and top coats to two equivalent (same number of each size) sets of trucks. One set was painted with the ULV gun, and the other with a conventional air atomizing gun, by painting shop staff at Warner Robins AFB GA.

METHODOLOGY: Standard procedures were maintained during tests. Painters wore supplied-air respirators, and airflow in the booths was verified by the Warner Robins bioenvironmental engineering (BEE) survey. BEE personnel also monitored representative painting sessions. A Zahn viscometer cup was used to measure viscosity at intervals corresponding roughly to refilling. Film thickness, measured using a thickness gauge (Inspector, Elcometer Instruments), is reported as an average of 10 determinations for each truck. Paint consumption was measured by weighing the paint gun systems full and after delivery, on a scale accurate to $\pm$0.02 pounds. Consumption was the net weight loss. VOC concentrations were measured with a flame ionization detector (Rosemount Model 400A Hydrocarbon Analyzer). Stack samples were delivered to the FID by ADI 01320T dual-head, Teflon^{R}-diaphragm pumps. Continuous VOC measurements were recorded on strip charts. Tabular VOC data were collected at 15-second intervals, integrated over time by application of the trapezoid rule, and compared to the mechanically integrated strip chart data to confirm calibration.

TEST DESCRIPTION: The test consisted of measuring paint consumption, VOC emissions, and paint coat thicknesses during painting of each of 14 trucks. However, experimental irregulrities caused elimination of the data from the first weekend, leaving only two 2.5-ton and two 5-ton trucks as the sample population for each treatment group. Personal exposure sampling was conducted by the BEE group during one of the tests performed with each of the guns. The painters and shop supervisor were surveyed for their impressions of the two guns.

RESULTS: After normalization to correct for coat thickness, paint consumption of the CARC topcoat applied with the ULV gun averaged 20 percent less than with the conventional unit. The ULV gun lowered VOC emissions by nearly 50 percent, a result of greater transfer efficiency (noted above) and the capability of the ULV gun to deliver undiluted, high-viscosity paint. A qualitative decrease in density of overspray was seen during the study. Personal exposure data are complicated by the occurrence of a solvent spill during the exposure test for the ULV gun, but still show that the ULV gun creates no increase in exposure compared to the conventional gun. Impressions of the ULV gun were uniformly favorable, both about its handling and about the coat delivered.

CONCLUSIONS: The ULV gun delivered satisfactory prime and top coats. Transfer efficiency was significantly better than for the conventional gun. Both of the latter observations have potential to lower the rate of VOC emission associated with spray painting.

RECOMMENDATION: The ULV gun should be examined further, both to determine suitability for specific applications to ground equipment, aircraft, parts, etc., and to establish optimal viscosities for application to minimize VOC emissions consistent with satisfactory coat thickness and characteristics.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Section I

INTRODUCTION

The content of this report is the result of a study carried out by Pandalai Coatings Company (PCC) to evaluate two innovative painting processes. The study was carried out under contract #68D00088 for the Air Force Civil Engineering and Support Agency and the Air and Energy Engineering Research Laboratory (AEERL) of the Environmental Protection Agency in RTP, North Carolina. The two innovative painting processes included were the UniCarb process, and Air Compliance Technologies' Ultra-Low Volume (ULV) spray process. A brief description of the fundamental principles involved in the two processes is given in the following sections.

A. OBJECTIVE

The objective of this study was to evaluate and define the painting efficiency and benefits of two selected painting systems. The study was conducted through laboratory evaluations and operational evaluations at a painting facility. Each system was required to be able to apply the complete range of USAF coatings applicable with conventional spray technology. The systems were also required to utilize typical USAF coatings including high solids coatings.

B. BACKGROUND

1. UNICARB Process

In the UniCarb process, carbon dioxide (CO_2) is used under supercritical conditions to replace part of the coating solvent formulation that is used to dilute the coating to the required spray viscosity. The amount of carbon dioxide that can be added depends on the resin system and the type and amount of solvents that are present in the resin system. The UniCarb system has several advantages:

a. Pollutant emissions are significantly reduced since the coating solvent loading is reduced, therefore health hazards from potentially toxic solvents are reduced.

b. The possible reduction of VOC emissions from the spray painting operations may permit compliance with the Clean Air Act.

c. Waste by-product carbon dioxide can be used.

d. The cost of bulk carbon dioxide is 50 to 60 percent less than the cost of solvents used in modern coating systems.

e. System can reduce or eliminate the need to use viscosity modifying diluent organic solvents or thinners.

Laboratory experiments on the ability of the technology to apply USAF specification coatings were conducted at the Union Carbide West Charleston WV research facility. Since the coating would be diluted with an alien compound (CO_2) and heated, compatibility, application, and pot life of the two-component system were evaluated. USAF specifications require the pot life for mixed two-component urethane coatings to be at least four hours. In addition, the coating quality must meet the requirements for gloss, orange peel and other surface and functional properties.

It was found that the UNICARB system is not capable of utilizing two-component systems without premixing. Thus the two-component urethane used for the evaluation was mixed in a separate vessel during the laboratory evaluations and combined with carbon dioxide within the system. Since the present UNICARB system heats the premixed coating for use with the high pressure carbon dioxide, premature setting of the coating occurs. Based on this limitation the system could not meet the pot life specification for the mixed coating. This one limitation eliminated the UNICARB system from further consideration during the evaluation program. Thus this technology, used under its current operating conditions, was considered incompatible with present USAF two-component topcoats.

2. Air Compliance Technologies' ULV Process

In the ULV process, compressed nitrogen gas acts upon the back of a floating piston to force paint through a spray gun and the nozzle. Depending upon the viscosity and solids content of the paint and the size of the tip opening, the pressure of the nitrogen gas in the cylinder is adjusted between 700 to 950 psig. Spray gun tip openings range from 0.012 to 0.020 inches. As in conventional airless spray painting operations, the paint is driven from a container by a displacement pump and compressed at the top of the piston atop the nitrogen cylinder. When the spray gun is triggered, paint is pushed through the nozzle opening at a constant flow rate. Unlike compressor operated systems, which surge at each stroke of the pump, this constant flow rate permits deposition of the coating at an even, uniform thickness. Theoretically this eliminates peaks and valleys, which necessitate multiple passes over the surface. The uniformity of thickness allows the usage of less paint, thus increasing the painting efficiency in area covered per unit of paint used.

C. SCOPE/APPROACH

An examination of the Unicarb and ULV systems indicates that the two technologies are at different stages of development. The ULV system appears to be a simple system that is suitable for operations in small job shops as well as in a large painting operations. The Unicarb system is geared toward larger painting operations utilizing single component coatings. The Unicarb system could not be used during the field testing phase using any of the aerospace two-component coating systems, due to problems of paint clogging. However, since the ULV system did not exhibit these problems, it advanced to on-site testing and evaluations at an operating USAF facility.

The system evaluation objectives were accomplished through a series of tests, beginning with the laboratory testing of the Unicarb and ULV systems. Upon successful completion of the laboratory evaluation, the ULV system was evaluated at an operating facility. Factors evaluated during laboratory and field testing included surface quality, pot life, relative emissions generated during painting (compared to conventional painting system emissions), volume of paint used per unit area covered, amount of solvent contained in the applied paint, and ease of use of the system.

Since the Unicarb system was eliminated from further evaluation after the initial laboratory studies were completed, additional discussions of that system are omitted from this report.

Section II

LABORATORY EXPERIMENTAL PHASE

The paint system used during initial laboratory evaluations included a MIL-P-23377 primer and a MIL-C-83286 topcoat. Specially formulated high-viscosity variants of the above coating were used for the laboratory evaluation phase. This low-VOC topcoat system nominally conforming to MIL-C-83286 was specially formulated by and procured from Crown Metro Aerospace Coatings Company in Greenville, South Carolina. Two colors, camouflage grey and white, were shipped to Atlanta, Georgia, for initial laboratory evaluation. Based on data obtained from Crown Metro, the volume of solids was 50 percent and the VOC content of both the grey and the white was less than 3.5 pounds per gallon of coating, the maximum amount of VOC permissible for compliance in many states. These data were verified in PCC's laboratories.

A. LABORATORY TESTING OF THE ULV PROCESS

Approximately 2 gallons of both white and grey camouflage colors were used for preliminary laboratory testing. Test panels were treated and primed by the Air Force Materials Laboratory, Wright-Patterson AFB OH, and supplied to the test laboratory for topcoating. The final preparation of test panels, with the application of the topcoat, was carried out at the BASF research facility near Atlanta GA.

Since the ULV technology is based on the application of nitrogen pressure to force the high-viscosity coating through the nozzle, the atomization will depend on the temperature of the coating at the time of application, rheological properties of the coating, and nozzle opening. These settings were determined and panels prepared for quality assurance laboratory evaluations at Wright-Patterson AFB.

Work with the specifically modified high-solids coating presented a number of problems during the laboratory phase of the project. One problem encountered was slow drying of the modified coating. Work carried out at PCC laboratories and at the Air Force Materials lab confirmed that the problem was due to insufficient catalyst to promote rapid and complete drying. It was therefore decided to utilize the standard compliant two-component urethane coating system MIL-C-85285 for all the further evaluations.

This coating system and the ULV process had never been utilized before at Warner Robins Air Logistics Center. Therefore, the Air Force corrosion group and the F-15 engineering group required that test panels be prepared and tested for compliance with the substitute coating system before permission for the field test program could be granted. Test panels of 2024-T0 and 2024-T3 aluminum were anodized, chromate conversion-coated and primed with MIL-P-23377 epoxy primer. These panels were allowed to dry for 3 to 4 hours and sent to the ULV corporation for application of the MIL-C-85285 top coat. They were then sent to the Naval Air Development Center (NADC) laboratories for compliance testing. Quality approval of the test panels was granted by the NADC laboratory. Approval for field testing of the ULV system was granted by the site engineering authority based on the NADC approval of the test panels.

Although it was originally planned to paint F-15 aircraft parts, military vehicles belonging to the Air Logistics group were substituted for the field testing. This change ensured a steady supply of similar items to be painted over a predictable length of time. The change also necessitated a change in paint. Initially it was scheduled that a two-component polyurethane coating, MIL-C-46168, for which the VOC content is 4.65 pounds per gallon would be used for the testing. However, due to changes in military vehicles, a single-component moisture-curing polyurethane, MIL-C-53039, for which the VOC content is 3.50 pounds per gallon was used as the topcoating system.

The test program was scheduled to be carried out during three successive weekends in September 1991. The parameters to be monitored included paint consumption, total hydrocarbon emission, paint dry film thickness, and worker comparison and opinions, for both the ULV and conventional air and airless spray painting processes.

Section III

FIELD TESTING

A. EXPERIMENT

The site selected for the field test program was Warner Robins Air Logistics Center, where F-15, C-130, and C-141 military aircraft are repaired and maintained. The component painting shop located in building 180 was selected as the location for the painting evaluations.

An experimental plan was devised to test the ULV system against the conventional pressure pot spray systems by comparing the following parameters and variables.

- Exhaust VOC concentrations
- Paint consumption per unit area
- Surface area covered
- Spray tip size
- Spray pressure
- Solvent content of coating system
- Viscosity of paint
- Film thickness
- Total estimated VOC emissions

The evaluations were run on three consecutive weekends, 13 September 1991 to 27 September 1991. Equal numbers of both 2.5- and 5-ton trucks were painted. During the first weekend, six trucks were monitored; three 2.5-ton and three 5-ton vehicles. During the next two weekends a total of eight trucks were monitored--four of each size.

Such baseline data as exhaust fan airflow rate and paint composition had to be obtained from the paint shop records. Fan flow rates (Table 1) for each booth were measured in June of 1990 by the Warner Robins Bioenvironmental Engineering Group. The coating content was obtained from the Material Safety Data Sheet (MSDS).

TABLE 1 AIR FLOW RATES FOR EACH BOOTH

Equipment	Measured CFM
Paint Spray Booth # 733	39,029
Paint Spray Booth # 734	66,243

1. Viscosity Measurements

The viscosity of the paint was measured by using a Zahn viscometer cup. Viscosity measurements were generally taken each time the large pressure pot or container for the ULV system was refilled. This ensured that the paint viscosity was approximately constant throughout the test.

2. Thickness Measurements

The dry film thickness of the paint was measured using an Inspector^{R} thickness gauge by Elcometer Instruments. Ten dry film thickness measurements were taken at different locations on each truck and averaged.

3. Paint Consumption

To measure the weight of the paint used, a method by which the spray gun, hose, and paint container were weighed together was devised. An Ohio Valley Industrial scale accurate to 0.02 pounds gave weights before and after each painting cycle. These measurements permitted a determination of paint consumption, and indirectly were used to calculate total VOC emissions.

4. VOC Measurements

A Rosemount model 400A flame ionization detection Hydrocarbon Analyzer was used to measure VOC concentration in the exhaust duct. Outputs from the machine are in the form of a digital readout and a variable DC output suitable for a standard strip chart recorder. From the strip chart recorder output, an integration over time was used to calculate the total emissions during the duration of the experiment.

Booths numbered 733 and 734 located in building 180 were used for the painting evaluations, and their exhausts were sampled for total VOC emissions. Emission samples from the booths were drawn in parallel by an ADI 01320T dual-head Teflon^{R} diaphragm pump. This arrangement allowed valves to be put on both suction ends of the pump, which created two separate sampling lines--one for each booth. Both booth #733 and #734 have two separate fans and stacks, and sampling took place just beyond each exhaust fan. Since each spray booth had two stacks both stacks were sampled simultaneously or the sample combined from both to obtain a representative result for booth emissions. Figure 1 is a schematic diagram of the sampling arrangement.

B. Analytical Methods

VOC emissions data in parts per million (ppm) were obtained in two forms, strip chart recordings, and total VOC emissions taken every 15 seconds and saved in spreadsheet form. Two methods were subsequently used to analyze these two data sets. A Planix digital rolling planimeter was used to calculate the area in square inches under the curve drawn as the strip chart recorder output. This area was then converted into the appropriate units of ppm-sec. The spreadsheet of output

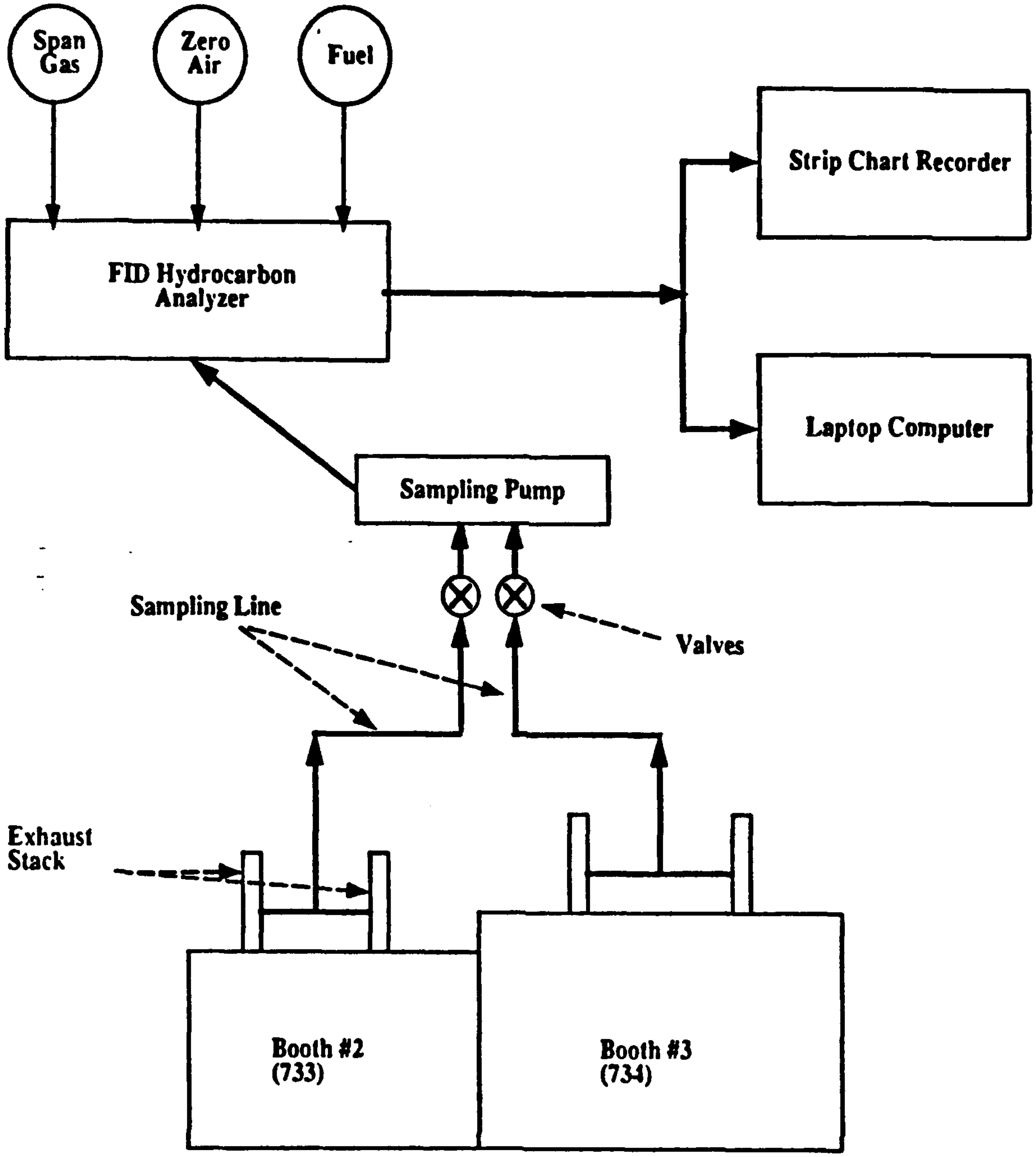


Figure 1 Schematic Diagram of VOC Sampling

measurements, taken at equal time intervals, conveniently lends itself to a simple mathematical manipulation via the trapezoidal rule equation:

$$AREA = (y_0 + 2y_1 + 2y_2 + 2y_3 + \ldots + y_n)*(b-a)/2n$$

Although this is not an exact integration of the curve created by the digital data, use of the trapezoid rule provides an estimate of the area under a series of sensor readings(i.e.,n readings create n-1 trapezoids). The sum of the area of these trapezoids is approximately the area under the curve. The quality of the approximation improves as the number of intervals increases. as the typical period of accumulation is about an hour and the data were sampled at 15-second intervals, area so calculated are a reasonable approximation of the true area. A graphical illustration of this method is shown in figure 2.

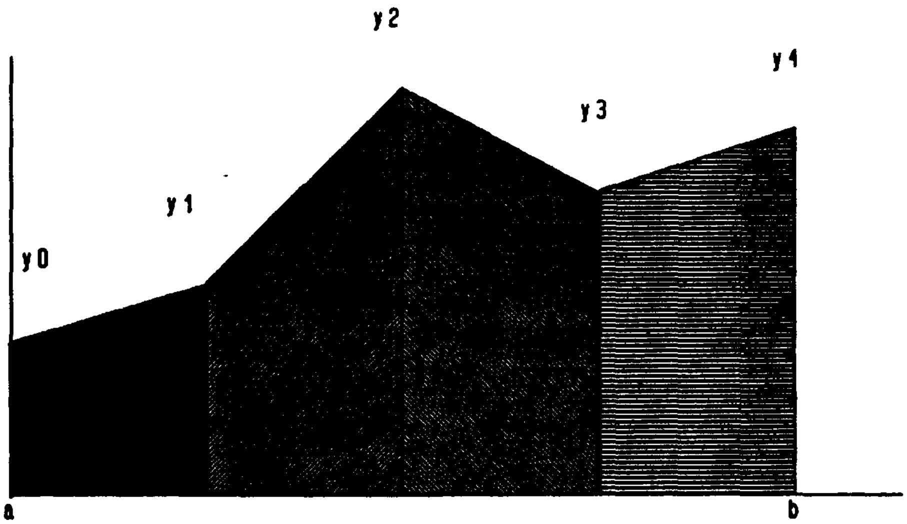


Figure 2 Graphical Illustration of Trapezoid Rule

C. RESULTS

Measurements of emissions during testing are given in Table 2 on page 9. It gives the amount of paint used for each priming and topcoat operation, and the final dry film thickness--where it was measured--on each truck. Measurements of emissions are also provided for analysis. These graphs are the basis for the conclusions and recommendations of the report. Figure 3 overlays displays of the amount of VOC measured versus time during painting of nominally identical 2.5-ton trucks with the conventional and ULV guns. From this figure, it can be seen that the overall emissions rates from the ULV system are only two-thirds that for the conventional spray gun. This run provides a good comparison between the two spray systems for many reasons. First, operator bias is eliminated because the same operator used both systems. Second, the duration of priming of the trucks is approximately the same, so background emissions will not be a factor. Finally, both systems were used on "identical" trucks in the same booth, so the effect of these variables can be considered equivalent for this comparison.

In Figure 3, it is easy to misinterpret the conventional spray readings as lower than actual. This is because, in the conventional process of priming, the two-component primer, MIL-P-23377, was first thinned and then sprayed using one-quart, cup guns. Valleys in the VOC emission curve indicate the time during which the cup guns were refilled when using the conventional system. Table 3 shows the refilling schedule for

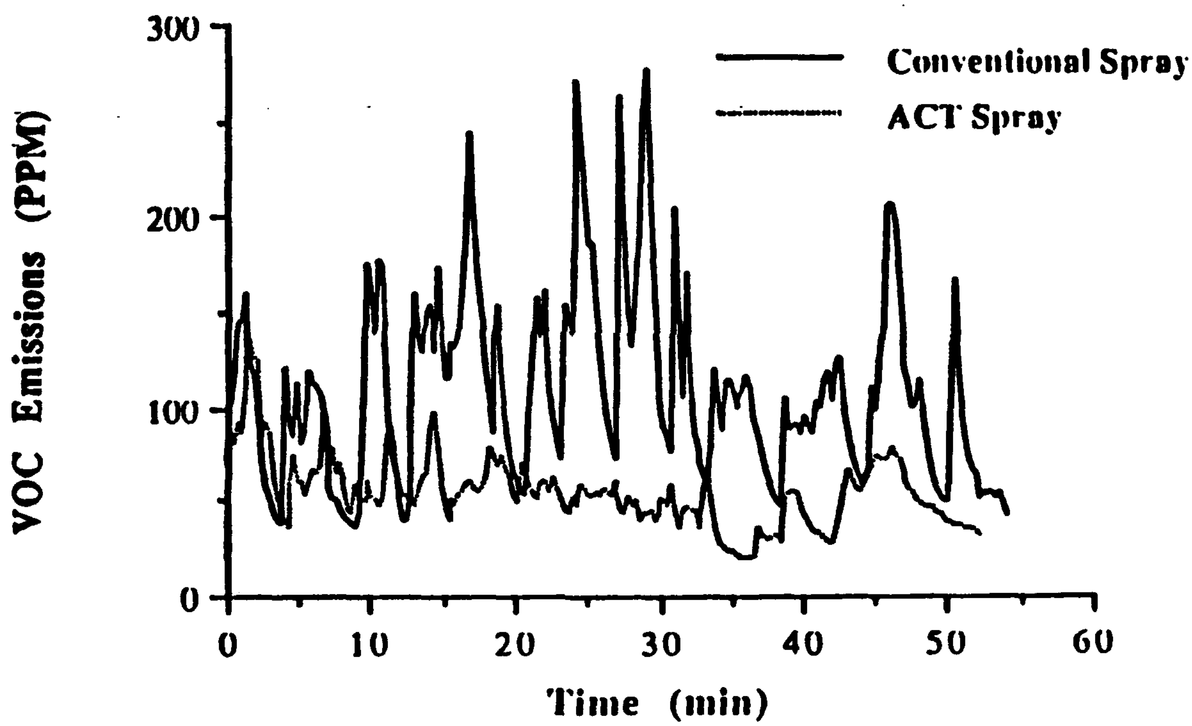


Figure 3 Emissions Comparison of ULV and Conventional Spray Prime Coat, Night Shift, 20 September 1991

the cup guns used in this particular run. Comparison of the chart and the graph verifies the correspondence between the valleys in the pattern of VOC emissions from the conventional system and the times when the gun was refilled. No such valleys appear in the process line for the ULV spray, on which refilling was not necessary because the ULV system comes equipped with a four-gallon storage unit for spraying. This volume was usually sufficient to complete painting of one unit.

TABLE 2 Amount of Paint Used and Dry Film Thickness for Each Truck Painted

DATE	BOOTH NO.	TRUCK ID#	TRUCK SIZE	METHOD	COAT	PAINT USED	FILM THICKNESS
			TONS			LBS	MIL
9/13	2	87K1703	2.5	CONV.	PRIMER	24.4	*
9/13	2	87K2085	2.5	CONV.	PRIMER	19.89	*
9/13	3	85K479	5	ULV	PRIMER	9.57	*
9/13	3	83K3	5	ULV	PRIMER	6.23	*
9/13	2	87K1703	2.5	ULV	TOP	88.12	10.5-12
9/13	2	87K2085	2.5	ULV	TOP	*	10.5-12
9/13	3	85K479	5	ULV	TOP	107.5	10- 12
9/13	3	83K3	5	ULV	TOP	*	10- 12
9/14	2	87K2347	2.5	CONV.	PRIMER	12.3	*
9/14	3	83K1	5	CONV.	PRIMER	17.3	*
9/14	2	87K2347	2.5	CONV.	TOP	44.2	6- 7.5
9/14	3	83K1	5	CONV.	TOP	52.9	6- 7
9/20	2	87K1991	2.5	CONV.	PRIMER	6.26	*
9/20	2	87K2133	2.5	CONV.	PRIMER	6.2	*
9/20	3	87K1695	5	CONV.	PRIMER	16.16	*
9/20	3	87K2086	5	CONV.	PRIER	10.92	*
9/20	2	87K1991	2.5	CONV.	TOP	31.9	5-7
9/20	2	87K2133	2.5	CONV.	TOP	50.1	6-7.5
9/20	3	87K1695	5	CONV.	TOP	60.4	7-8
9/20	3	87K2086	5	CONV.	TOP	53.7	6-7.5
9/27	3	86K9107	5	ULV	PRIMER	9.9	*
9/27	3	87K3323	5	ULV	PRIMER	*	*
9/27	2	86K10086	2.5	ULV	PRIMER	5.9	*
9/27	2	87K10091	2.5	ULV	PRIMER	*	*
9/27	3	86K09107	5	ULV	TOP	95.3	8-10
9/27	3	87K03323	5	ULV	TOP	*	*
9/27	2	85K10086	2.5	ULV	TOP	83.4	6.5-8
9/27	2	87K10091	2.5	ULV	TOP	*	*

* no data available

NOTE: Due to inconsistencies in the spray process, clogging, spillage, and operator error, data from the first weekend of testing were not used for purposes of analysis, although they are presented here.

TABLE 3 REFILLING CHART FOR CUP GUN

Time	Cup Weight Before (lbs)	Cup Weight After(lbs)	Total Weight(lbs)
4	5.60	3.26	2.34
9	5.72	3.46	2.26
12	5.72	3.30	2.42
19	5.64	3.28	2.36
21	5.52	3.30	2.22
23	5.54	3.26	2.28
27	5.52	3.24	2.28
31	5.54	3.16	2.38
34	5.42	3.68	1.74
39	5.42	3.20	2.22
45	5.44	3.18	2.26
50	5.50	3.18	2.32

Section IV

DATA ANALYSIS

Copies of the strip chart recorder data are in Appendix A, and the raw numerical data appear in spreadsheet form in Appendix B. Also included on the spreadsheet are calculations of painted area and paint used. This will be addressed later in this section. Table 4 lists the conditions for each individual prime and top coat run. Individual graphs and accompanying tables follow in this report. When analyzing the data, several factors that affect emissions must be considered:

- Operator error
- Paint shop procedures
- Spills/leaks of paint and/or thinner
- Ambient ventilation conditions
- Direction of spray by operator

Table 4 TEST DATA FOR ALL PRIMER AND TOPCOAT RUNS

Date	Truck ID#-Size	Booth Number	Painting Time Minutes	Spray Equipment	Pressure PSI	Spray Tip Size mm	Coating Type	Thinner To Coating Ratio	Viscosity seconds
9/13/91	85K479-5TON	3	15	ULV	775	12	Primer	1/4.6	16
"	83K3-5TON	3	20	"	600	12	Primer	1/3.0	21
"	83K3-5TON	3	300?	ULV	800	12-20	Top Coat	*	*
"	85K479-5TON	3	300?	"	800	12-20	Top Coat	*	*
"	87K1703-2.5TON	2	61	ULV	100	30	Primer	1/11.8	23
"	87K2085-2.5TON	2	44	"	100	30	Primer	1/9.7	23
"	87K1991-2.5TON	2	13	"	100	30	Primer	1/3.0	23
9/20/91	87K2133-2.5TON	2	13	CONV	100	30	Primer	1/2.9	23
"	87K2086-2.5TON	3	45	"	100	30	Primer	1/7.4	21
"	87K1695-5TON	2	40	"	100	30	Primer	1/4.9	24
"	87K1991-2.5TON	2	158	CONV	100	30	Top Coat	1/4.0	29
"	87K2133-2.5TON	3	150	"	100	30	Top Coat	1/4.0	30
"	87K1695-5TON	3	150	"	100	30	Top Coat	1.5/4	21
"	87K2086-5TON	3	125	"	100	30	Top Coat	1.3/4	24
9/27/91	09107-5TON	3	45	ULV	600	10	Primer	1/4.5	18
"	03323-5TON	3	45	"	600	10	Primer	1/4.5	18
"	10866-2.5TON	2	45	"	1000	10	Primer	1/2.7	18
"	10091-2.5TON	2	45	"	1000	10	Primer	1/2.7	18
"	09107-5TON	3	85	"	1000	16,14	Top Coat	1/14.4	34
"	03323-5TON	3	85	"	1000	16,14	Top Coat	1/14.4	34
"	10866-2.5TON	2	120	"	800	14,14	Top Coat	1/12.6	34
"	10091-2.5TON	2	120	"	800	14,14	Top Coat	1/12.6	34

* No data available

Some data from the following analysis should not be included in the overall averaging because they involve one or more of the above factors, and do therefore not represent normal painting operations. These are identified for each instance. Figure 4 may be interpreted as follows: for the interval from approximately 12 to 15 minutes into the operation emissions drop drastically. This corresponds to the period from completion of spraying one vehicle until starting work on the next. During this changeover period, the paint container and gun were weighed to determine the amount of paint used for priming a single vehicle. The total time used to complete priming of both trucks, 25 minutes, is less than the total time recorded in Table 3 for the first two entries, because the entry in the table includes spraying time plus time required to clean the spray guns and the Spra-Pac ULV system.

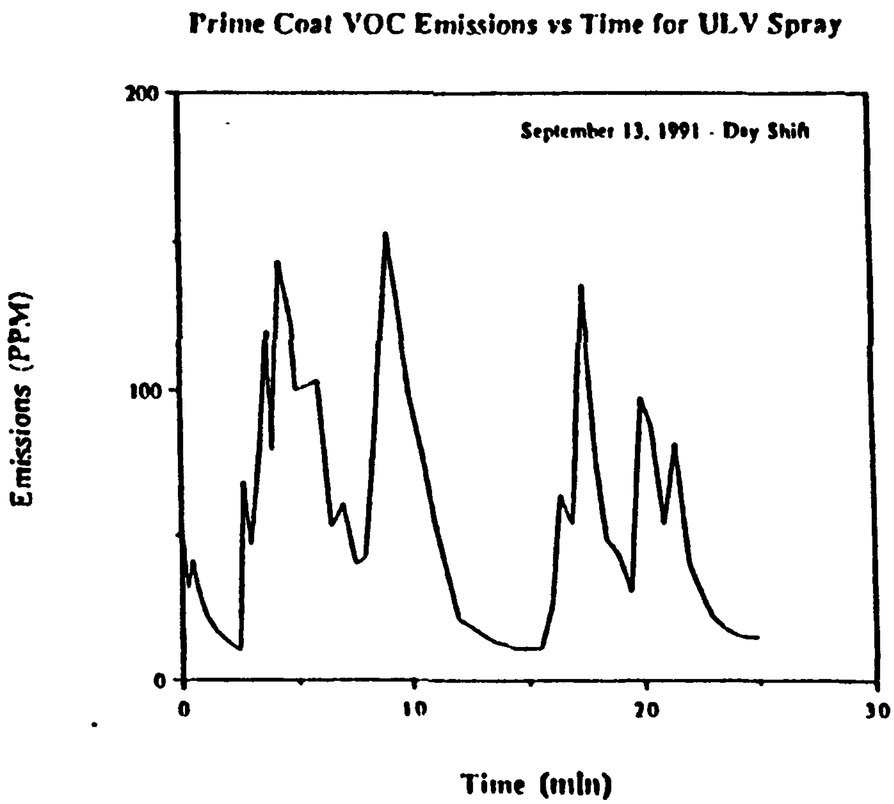


Figure 4 Prime Coat VOC Emissions vs Time For ULV Spray, Day Shift, 13 September 1991

The weight of primer given in Table 5 is the total weight of the cup and paint removed from the conventional spray apparatus. By subtracting the before and after weights, an accurate value for total weight change is obtained. As in the preceding example, each valley in the emissions graph, Figure 5, corresponds to a time when the one-quart cup gun used for priming

Prime Coat VOC Emissions vs Time for Conventional Spray

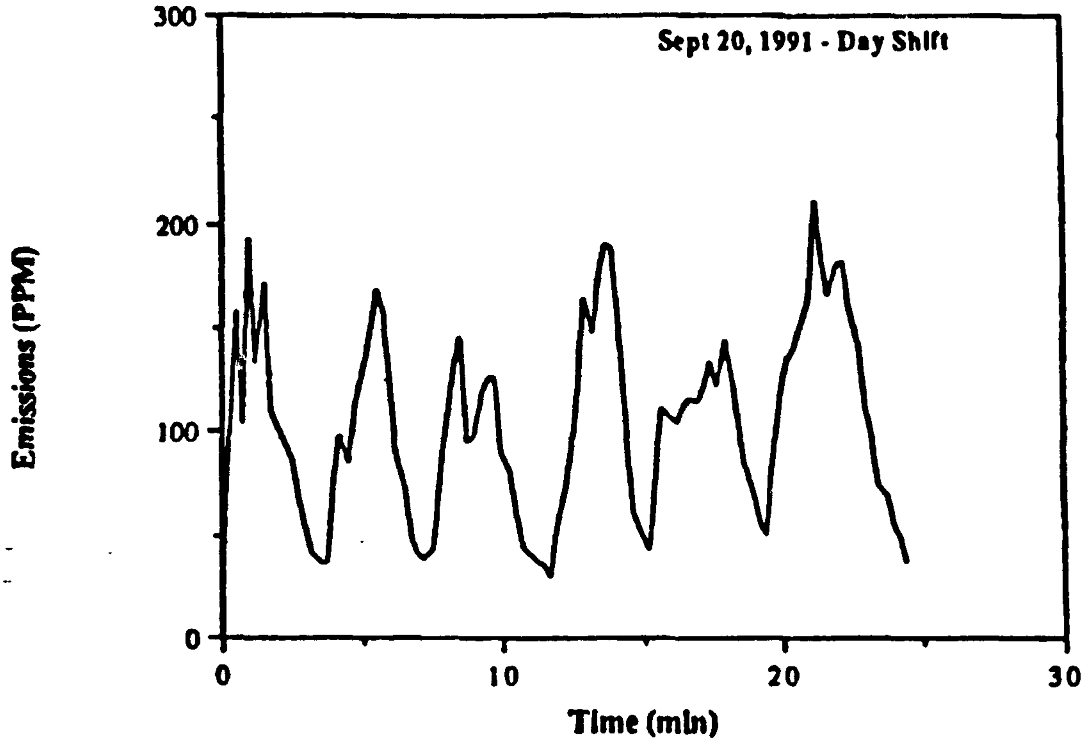


Figure 5 Prime Coat VOC Emissions vs Time for Conventional Spray Day Shift, 20 September 1991

needed to be refilled. Also, only one gun was running during the priming operation. The first operator finished at 1:03 p.m. and the second operator immediately began priming the second truck in the booth. Observations made on this run included comments that

Table 5 - REFILLING CHART FOR DAY SHIFT PRIMING ON 20 SEPTEMBER 1991

Time (min)	Primer Weight Before (lbs)	Primer Weight After (lbs)	Total Primer Weight (lbs)
4	5.32	3.14	2.18
7	5.36	3.14	2.22
12	5.50	3.64	1.86
	Total weight (6.26)		
(End Priming of Truck #87K1991 and Begin priming of Truck #87K2133)			
15	5.32	3.46	1.86
19	5.32	3.2	2.12
24	5.50	3.64	1.86
	Total Weight (5.84)		
	Total used (both Trucks) 12.1		

the prime coat varies in thickness. The foreman pointed out that this is a common occurrence as the prime coat is necessary only as an agent for the topcoat to adhere to the surface. Figure 5 and Table 5 represent day shift priming on 20 September 1991 of 5-ton trucks.

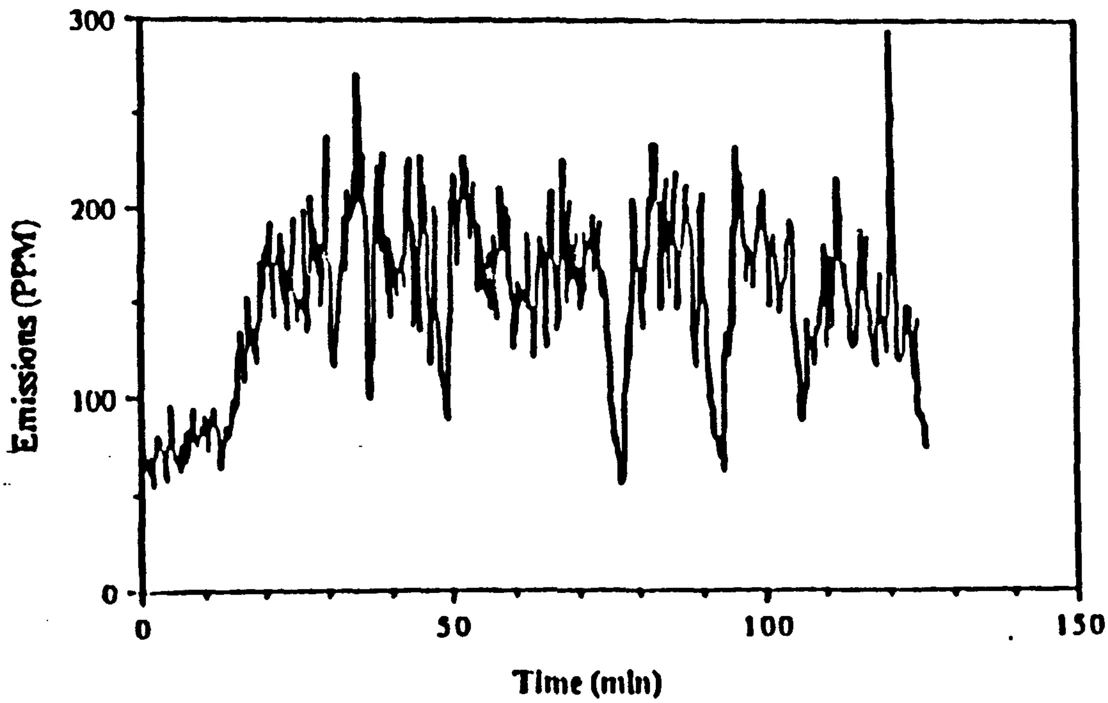


Figure 6 Top Coat VOC Emissions vs Time For Conventional Spray Day Shift, 20 September 1991

Table 6 REFILLING CHART FOR NIGHT SHIFT PRIMING ON 20 SEPTEMBER 1991

Time (min)	Cup Weight Before(lbs)	Cup Weight After(lbs)	Primer Total Weight (lbs)
4	5.60	3.26	2.34
9	5.72	3.46	2.26
13	5.72	3.30	2.42
21	5.64	3.28	2.36
23	5.52	3.30	2.22
27	5.54	3.16	2.38
31	5.54	3.26	2.28
34	5.42	3.68	1.74
38	5.52	3.24	2.28
45	5.42	3.20	2.12
51	5.44	3.18	2.26
56	5.50	3.18	2.32

Total Primer used (26.98)

Several features of Figure 6 are worthy of comment. During the first 15 minutes, the emissions are approximately half of the emissions during the rest of the operation because only one gun was operating at that time. The two valleys at 75-80 minutes and 95-100 minutes correspond to times when the painters were refilling their respective pressure pots. The emission peak value at 120 minutes occurred when the first painter cleaned his spray gun with solvent by spraying solvent into the booth.

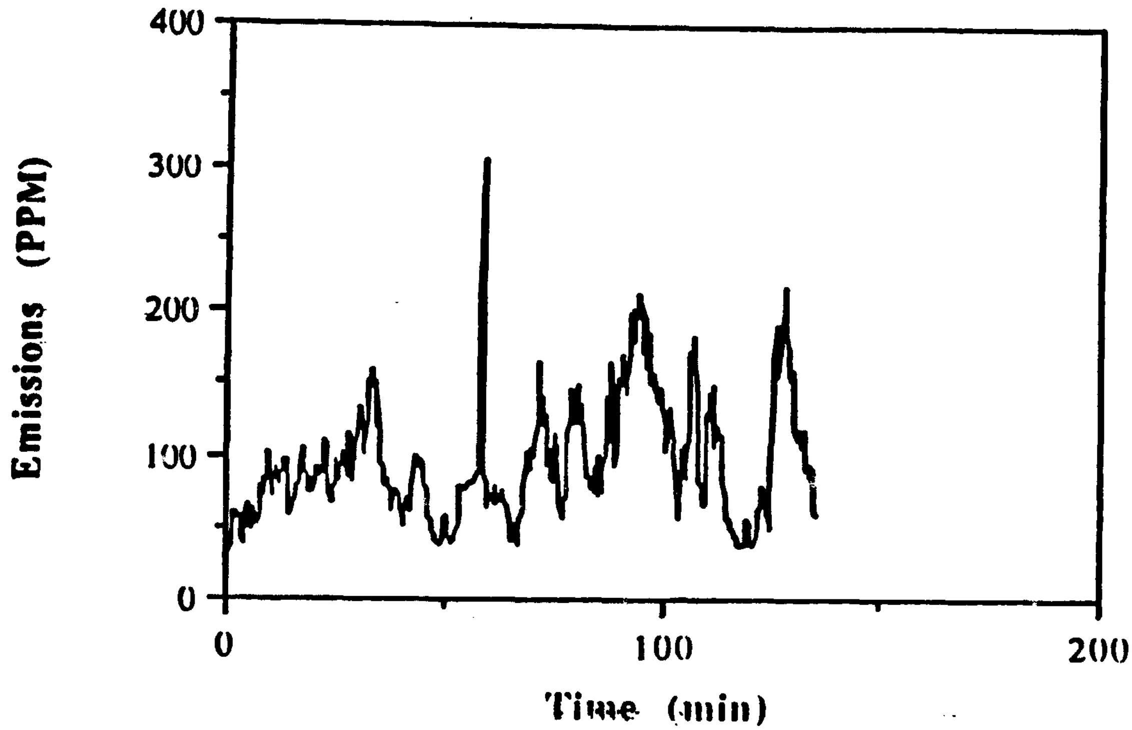


Figure 7 Top Coat VOC Emissions vs Time for Conventional Spray, Night Shift, 20 September 1991

Two anomalies in Figure 7 qualify for comment. The spike near 55 minutes, which rises to over 300 ppm, occurred when painting resumed before the booth exhausts were turned on. This caused the concentration of paint and paint solvents to build up. After rapidly rising, the concentration of paint and paint solvents also declined as rapidly when the exhaust fans were turned on. Second, the second painter used considerably more paint than the first because the second painter coated one truck but also did extensive touch-up work on both trucks in the booth.

The difference in emissions between one and two guns can be measured by overlaying data from the first 15 minutes in Figure 7 with a 15-minute segment later in that session. This is shown in Figure 8, which shows a noticeable difference between one- and two-gun application. Although the difference is not double, as might be expected intuitively, area calculations indicate the following:

	Area under Curve (total Emissions)
One gun	1191.56 ppm-minutes
Two guns	1798.54 ppm-minutes

The refilling chart for this sequence is given as Table 6. Figure 8 shows approximately a 50-percent increase in emissions between one and two guns. Data of this type are not available for the ULV spray system because, when the ULV system was operated for priming, only one gun was used. However, for topcoats, two guns were used. No comparison of emissions between the top coat and the primer for the purpose of comparing one- and two-gun emissions for ULV would be relevant.

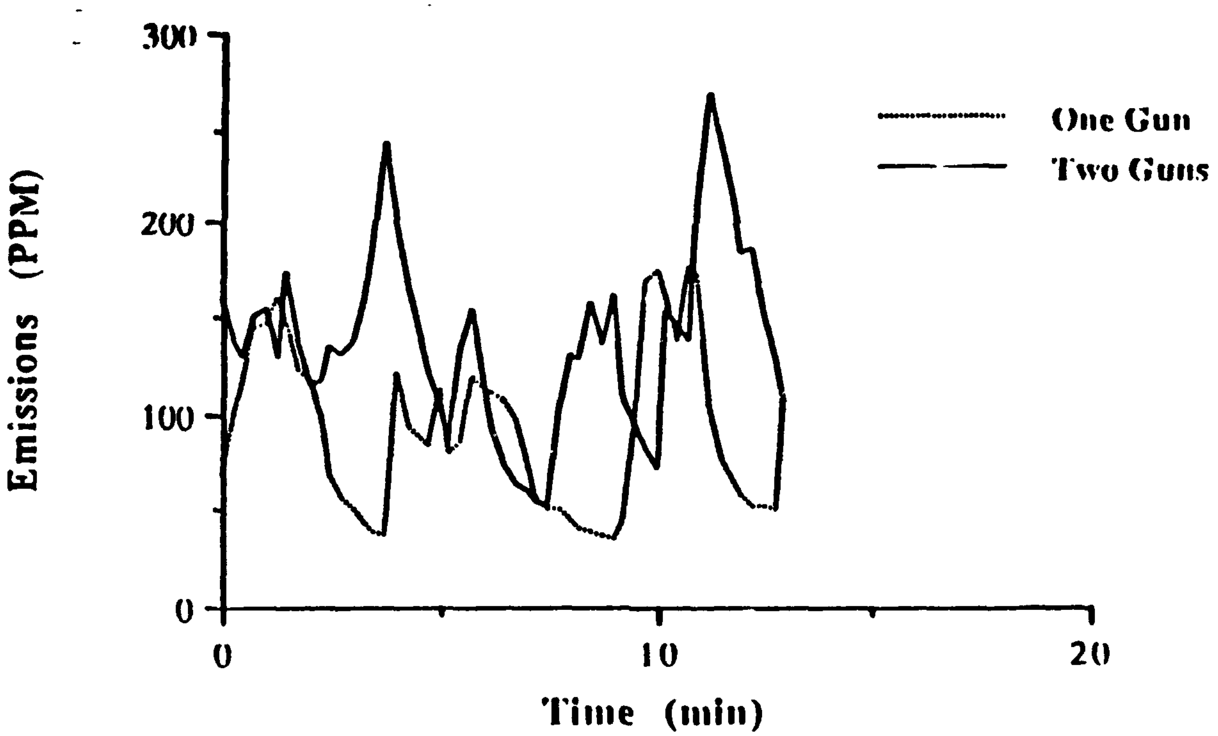


Figure 8 One Gun vs Two Guns — Con'_ntional Spray Gun, Primer

A. ULV DATA

When examining the data for the ULV spray system, one must keep in mind several differences between the spray methods. During this testing, only one ULV unit was used. For this reason, only one weight is recorded for every two trucks either primed or painted. Finally, each time the ULV system was used, it had a different operator, so operator inconsistency is potentially a significant factor in this testing. One episode included both spillage and clogging of the guns, which caused both a time delay and an increase in VOC emissions. Operator proficiency with the ULV equipment can only improve with experience and familiarity.

Human factors data, based upon comments of operators at the time that they were using the equipment follow:

1. The ULV system was easy to handle.

2. There was better visibility of the progress of spraying, because there was less overspray.

3. The ULV system took less time to complete the same job.

Section V

PROCESS-DEPENDENT PAINT SPECIFICATIONS

The tests indicate that the viscosity and solids content is dependent on which painting process is used. To use the minimum amount of solvent or a high-solids coating, the airless system is preferable to the air-assisted painting process. As shown in Table 7, this study showed that the ULV system permitted the use of material at 40 seconds viscosity whereas the air assisted process tolerated only material to 24-second viscosity.

TABLE 7 PROPERTIES OF MATERIAL APPLIED BY ULV AND CONVENTIONAL SYSTEMS

Process	Zahn Cup #2 Viscosity (Sec)	% Solids
Conventional	18-24	30
ULV	40	50

Section VI

MATERIAL SAVINGS

Paint consumption for each process is given in the results table (Table 3). Although the weight difference is less than 10 percent, this figure should not be viewed alone. The dry film thickness of the coating must also be taken into account. It is reasonable to extrapolate the paint used for a particular thickness as a linear function of the dry film thickness. In this analysis, since the ULV system's dry film thickness exceeded the conventional in each case, the amount of paint used for the conventional system was normalized to give the same dry film thickness. Based on this, Table 8 shows that the weight of the coating on two trucks painted with the conventional system would be 144.97 pounds whereas the ULV system used only 95.3 pounds--which gives a material savings of approximately 34 percent for an equal coating thickness.

Table 8 NORMALIZED MATERIAL SAVINGS FOR 5-TON TRUCKS

Truck ID	Method	Actual Mass (lbs)	Normalized Mass (lbs)
87K1695	Conventional	60.4	80.53
87K2086	Conventional	53.7	64.44
86K09107	ULV	--	--
87K03323	ULV	95.3	95.3

In the case of 2.5-ton trucks, using the same assumptions as for 5-ton trucks, the normalized material savings is shown in Table 9. In this example, the normalized sum of the paint used on the two trucks with the conventional system is 92.4 pounds whereas the ULV system used only 83.4 pounds, which gives a material savings of approximately 10 percent. This savings was lowered by an incident of spillage of paint and by episodes of clogging problems with the ULV system. These may be avoided when operators become more familiar with the system.

Table 9 NORMALIZED MATERIAL SAVINGS FOR 2.5-TON TRUCKS

Truck ID	Method	Actual Mass (lbs)	Normalized Mass (lbs))
87K1991	Conventional	31.9	38.6
87K2133	Conventional	50.1	53.8
86K10866	ULV	--	--
87K10091	ULV	83.4	92.4

Averaging the two values for material savings gives a minimum average of 22 percent. An equivalent statement is that the topcoat consumption is at most 80 percent of the usage by the conventional system. Sources at Mobay Corporation report that approximately 5 million dollars are spent annually on the MIL-C-85285 coating. A 20-percent savings in coating cost for the two aircraft topcoats represents a savings of one million dollars annually. These are rough estimates, and a detailed cost study is warranted to develop actual costs and estimates of savings.

Section VII

WORKER SAFETY AND HEALTH EFFECTS

Limited health effects data were taken. Air sampling in the painters' breathing zones was conducted for both conventional and ULV spraying operations. The samples were used to determine airborne concentrations of various contaminants. Samples were analyzed for methyl isoamyl ketone, butyl acetate, hexamethylene diisocyanate (HMDI), and total chromium.

Results of the sampling were not consistent with the stack measurements of hydrocarbons, which had previously shown much lower concentrations during the ULV operation than during use of the conventional method. The data in Table 10 are suspect because a spill of paint thinner occurred just outside the booth at the beginning of the ULV operation during these evaluations. This spill is suspected to have influenced the results obtained for the organic vapors. This conclusion is supported by the results obtained for total chromium (a particulate in the primer) emissions when sprayed. This was detected at 0.014 milligrams of chromium per cubic meter of air (mg/m^3) during the ULV operation and 0.038 mg/m^3 during the conventional operation (see table 10) It is reasonable to expect that if the observed elevation of VOC concentrations during use of the ULV system were produced by spraying primer there would be a commensurate increase in particulates. This was not the case.

Table 10 RESULTS OF WRALC AIR SAMPLING

Contaminant	ULV Results (mg/m^3)	Conventional Results (mg/m^3)
Total Chrome	0.014	0.038
HMDI	0.0034	None Detected
Total Chrome	Blank	Blank
HMDI	Blank	Blank
Butyl Acetate	11.3	12.5
Methyl Isoamyl Ketone	201	161
Butyl Acetate	38.3	1.2
Methyl Isoamyl Ketone	455	52
Butyl Acetate	Blank	Blank
Methyl Isoamyl Ketone	Blank	Blank

Because it appears that the measurements obtained for the organic vapors are not typical of normal ULV operation, they cannot reliably be used in comparison with those obtained during the conventional method as a means of evaluating worker exposure.

Section VIII.

QUALITY CONTROL

In any experimental data acquisition program, the quality of the data obtained must be verified for accuracy and bias. Factors involved in quality control include the number of trucks painted, the operator, such external conditions as temperature, humidity, ambient wind velocity, paint thinner spills, direction of spray, and thickness of coating. The quality of the experimental results improves with the number of objects painted and with increased operator familiarity with the ULV spray system.

A. DATA QUALITY INDICATORS

1. Precision:

The Rosemount 400A FID instrument is a very sensitive instrument with a response time of less than 0.6 seconds for 90 percent full-scale output. According to manufacturers specifications, the precision of the instrument is ±1 percent of full scale.

2. Bias:

The operating concentration range is a function of the full scale output to which the machine is calibrated. For example, if 1000 ppm methane span gas is used to calibrate at the 0 to 5 VDC output, a reading of 0.5 volts will indicate 100 ppm of total HC. According to manufacturers specifications, the bias of the instrument is ±1 percent of full scale over a 24 hour period.

3. Completeness:

The output of the blower (CFM, Table 1) through the stack is constant. As the total HC measurement can be read almost instantly by the instrument, there is no limitation on acquiring all necessary data upon which to base recommendations. Thus, the completeness is 100 percent.

4. Representativeness:

Zero gas and methane span gas are homogeneous mixtures, given that they are properly stored after procurement. They are expected to be representative gases that will have reliable response in the FID detector.

5. Sampling Procedure:

The total hydrocarbon measurement is performed in situ. A pump attached to the instrument continuously pulls the air under test through the FID. The instrument is initially calibrated and standardized prior to any measurements. A schematic of the sampling set up is provided in Figure 1.

6. Analytical Procedures:

The instrument was calibrated to display concentration in volts and percent full scale. Both downscale and upscale calibration points on the recorder and digital readout were first set using the following method. The zero standard gas (nitrogen) flows through the sample port while the zero point was set using the zero adjustment inside the instrument panel. The upscale point adjustment was made by using a standard span gas of known VOC concentration. For this experiment, 500 ppm methane in nitrogen gas was used.

Because the instrument used for VOC measurement is adjusted for zero with gas containing no VOCs, and the span gas used contained 500 pm methane, it was workable to check the zero reading and span calibration before and after each measurement run. This check gave instrument responses that fell within five percent of the expected value for every run. Examples of some of these readings are listed in Table 11 below. All of this information is in the raw data in spreadsheet form in Appendix B.

Table 11 SPAN GAS AND ZERO GAS CHECK AT END OF RUN

Run	Zero Gas (ppm)	Span Gas (ppm)
1	1.3	485
2	1.6	506
3	0.7	493

Section IX

CONCLUSIONS AND RECOMMENDATIONS

Data must be gathered on a much larger scale during field tests before information on transfer efficiency of the ULV system can be obtained on a strong statistical basis. However, this preliminary study does show that the process appears to offer advantages of decreased paint consumption, reduced overspray, and possibly lower risks to human health. Although this is implied by the results, more data are required before statistical inference can achieve a high confidence level.

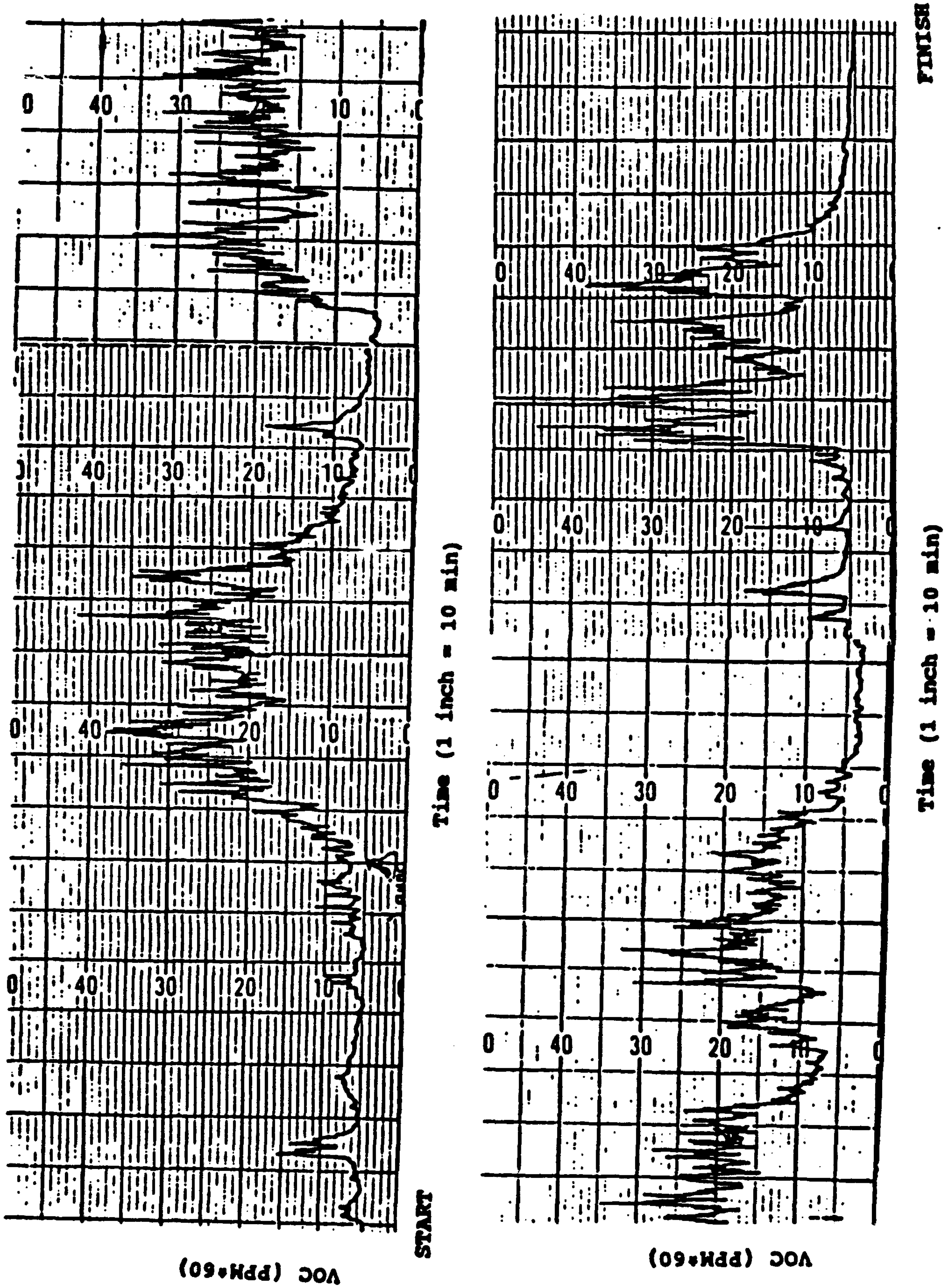
The evaluations indicate that a significant reduction in total VOC emissions is possible with the ULV system. The measurements collected indicate a 50-percent reduction in average VOC concentration. This can be confirmed by a corresponding average of 20-percent decrease in paint consumption. The product evaluation indicates that the ULV system is capable of producing comparable coating thickness with less paint, producing a lower concentration of VOC emissions, and being at least as safe as a conventional spray system in terms of health effects for the operators of the system.

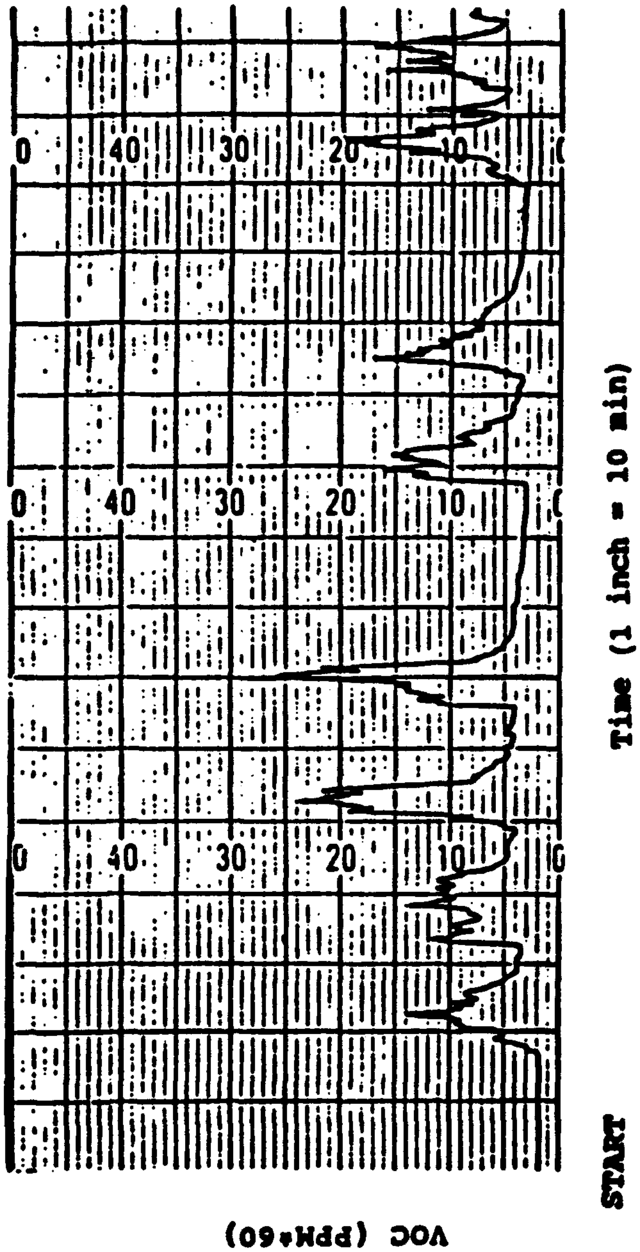
The operators also found the ULV system easy to use. There were unquantified labor savings based on the operator's observation of a reduction in the time needed to paint objects.

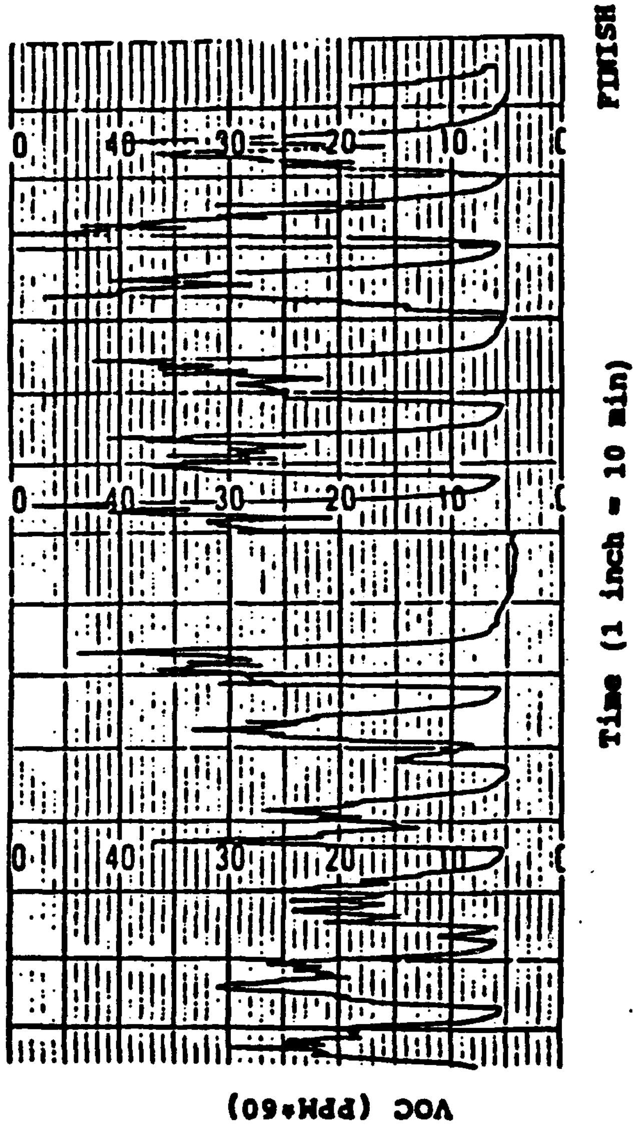
The average value for material savings appears to be about 20 percent. It is estimated that approximately 5 million dollars are spent annually on the MIL-C-85285 coating. A 20-percent material savings in this coating cost alone is equivalent to a savings of one million dollars. These 20-percent savings is only approximate, and a detailed study is necessary to develop actual cost and realistic savings.

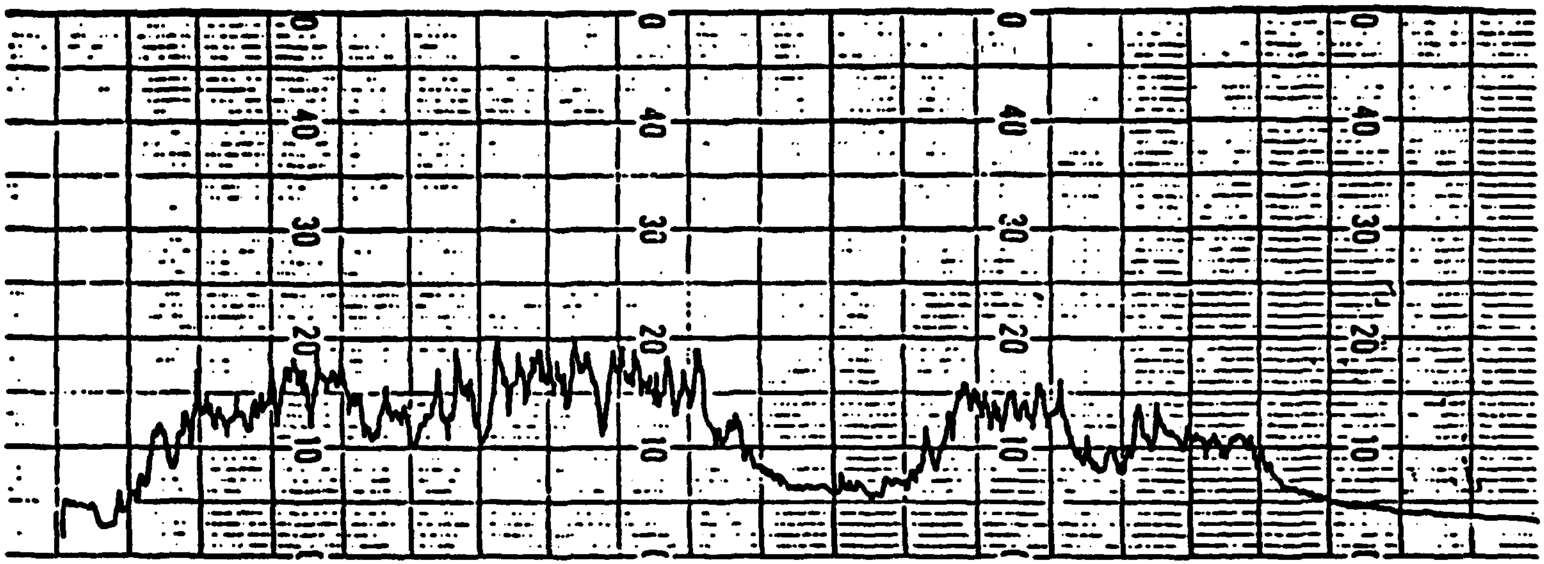
These preliminary findings indicate that a larger definitive operational test is needed to obtain a firmer statistical basis for the efficiency of the ULV painting system.

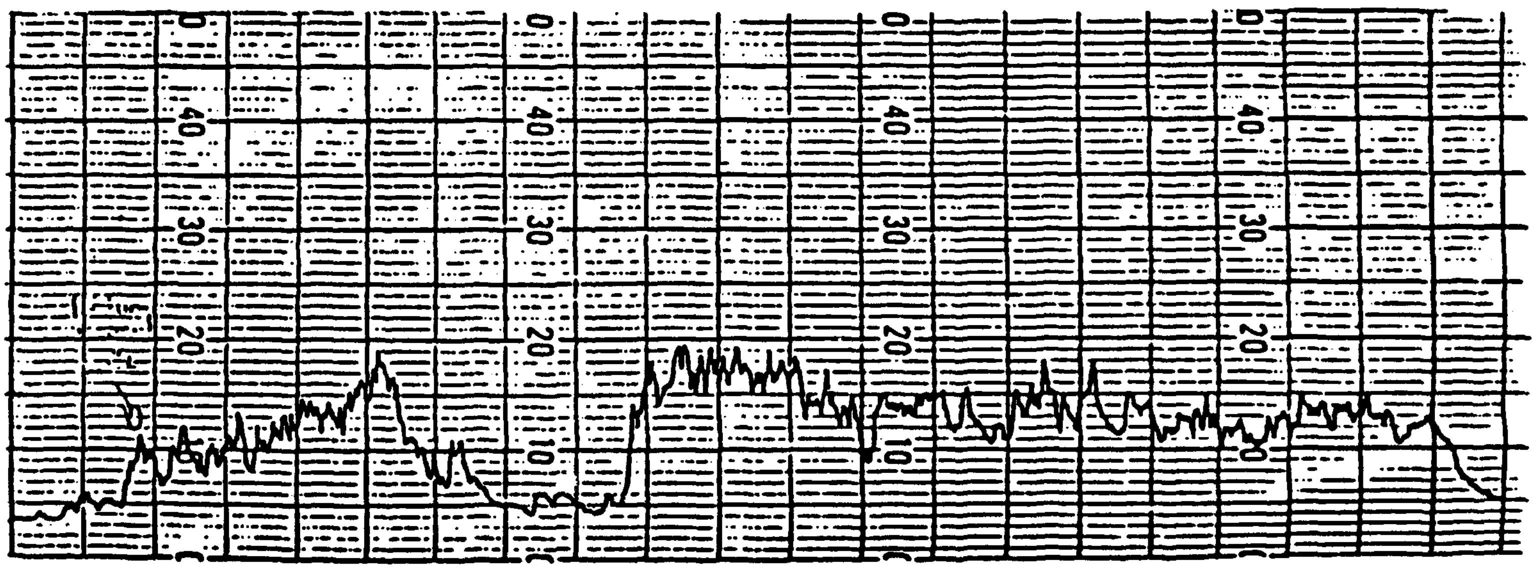
APPENDIX A - STRIP CHART RECORDER GRAPHS


START
FINISH
Time (1 inch = 10 min)
Time (1 inch = 10 min)
VOC (PPM*60)
VOC (PPM*60)
0 40 30 20 10 0


Time (1 inch = 10 min)
START
VOC (PPM*60)


Time (1 inch = 10 min)
FINISH
VOC (PPM*60)


VOC (PPM*60)
START
Time (1 inch = 10 min)


VOC (PPM*60)
Time (1 inch = 10 min)
FINISH

APPENDIX B - RAW DATA

TOPCOAT - BOOTH #3 TWO PRESSURE POTS

Time (min)	Trapezoid Area	VOC ppm
0	21.4	64.2
0.25	21.9	65.7
0.5	23.7	71.1
0.75	23.2	69.6
1	21.5	64.5
1.25	20.7	62.1
1.5	20.2	60.6
1.75	23.1	69.3
2	19.3	57.9
2.25	17.7	53.1
2.5	26.2	78.6
2.75	26.6	79.8
3	26.2	78.6
3.25	25.2	75.6
3.5	23.6	70.8
3.75	23.2	69.6
4	21	63
4.25	18.8	56.4
4.5	25.8	77.4
4.75	24.3	72.9
5	31.9	95.7
5.25	25.1	75.3
5.5	22	66
5.75	22.4	67.2
6	21.4	64.2
6.25	25.3	75.9
6.5	20.7	62.1
6.75	22.8	68.4
7	27.3	81.9
7.25	26.9	80.7
7.5	28	84
7.75	21.9	65.7
8	23.8	71.4
8.25	26.2	78.6
8.5	31.2	93.6
8.75	27.3	81.9
9	24.7	74.1
9.25	24.5	73.5
9.5	28.4	85.2
9.75	26	78
10	27.2	81.6
10.25	30.2	90.6
10.5	26.4	79.2
10.75	24	72
11	30.1	90.3
11.25	28.5	85.5
11.5	27.1	81.3
11.75	30.4	91.2
12	31.2	93.6
12.25	27.2	81.6
12.5	28.5	85.5
12.75	21.2	63.6
13	22.7	68.1
13.25	25.3	75.9
13.5	28.4	85.2
13.75	27.9	83.7
14	26.1	78.3

VOC Calculations
Area - Topcoat
9395.475

14.25	27	81
14.5	28.5	85.5
14.75	32.6	97.8
15	30.5	91.5
15.25	31.1	93.3
15.5	31.7	95.1
15.75	39.1	117.3
16	42.7	128.1
16.25	44.6	133.8
16.5	35.6	106.8
16.75	38.1	114.3
17	40.9	122.7
17.25	50.6	151.8
17.5	44.4	133.2
17.75	44.9	134.7
18	40.8	122.4
18.25	45.1	135.3
18.5	38.9	116.7
18.75	41.1	123.3
19	43.6	130.8
19.25	48.4	145.2
19.5	56.9	170.7
19.75	51.8	155.4
20	57.4	172.2
20.25	59.3	177.9
20.5	56	168
20.75	63.4	190.2
21	57	171
21.25	46.8	140.4
21.5	55.7	167.1
21.75	57.4	172.2
22	56.1	168.3
22.25	61.9	185.7
22.5	53	159
22.75	52.2	156.6
23	49.2	147.6
23.25	59.3	177.9
23.5	45.1	135.3
23.75	48.3	144.9
24	56.5	169.5
24.25	51.8	155.4
24.5	64.4	193.2
24.75	53.1	159.3
25	46.1	138.3
25.25	48.3	144.9
25.5	48.7	146.1
25.75	50.3	150.9
26	47.4	142.2
26.25	66	198
26.5	59.7	179.1
26.75	46.7	140.1
27	44.2	132.6
27.25	52.7	158.1
27.5	68.5	205.5
27.75	58.4	175.2
28	56.8	170.4
28.25	62.9	188.7

28.5	54.7	164.1
28.75	60.1	180.3
29	49.1	147.3
29.25	54.2	162.6
29.5	59.4	178.2
29.75	78.7	236.1
30	76.4	229.2
30.25	63.3	189.9
30.5	53.1	159.3
30.75	42.4	127.2
31	39.5	118.5
31.25	38.2	114.6
31.5	44.5	133.5
31.75	45.2	135.6
32	55.9	167.7
32.25	53.1	159.3
32.5	65.1	195.3
32.75	59	177
33	55.1	165.3
33.25	69.5	208.5
33.5	65.6	196.8
33.75	64.7	194.1
34	63.9	191.7
34.25	65.5	196.5
34.5	72.7	218.1
34.75	66.3	198.9
35	89.8	269.4
35.25	73.7	221.1
35.5	68.4	205.2
35.75	65.8	197.4
36	76.1	228.3
36.25	56	168
36.5	34.3	102.9
36.75	32.6	97.8
37	41.5	124.5
37.25	39.3	117.9
37.5	44.1	132.3
37.75	59	177
38	74	222
38.25	63.8	191.4
38.5	58.2	174.6
38.75	72.1	216.3
39	76.1	228.3
39.25	61.8	185.4
39.5	51.1	153.3
39.75	61.7	185.1
40	46.5	139.5
40.25	61.3	183.9
40.5	52.9	158.7
40.75	58.1	174.3
41	50.4	151.2
41.25	53.5	160.5
41.5	52.6	157.8
41.75	56.4	169.2
42	56.8	170.4
42.25	57.6	172.8
42.5	52.2	156.6
42.75	72.8	218.4
43	72.6	217.8
43.25	75.1	225.3
43.5	65.6	196.8
43.75	45.6	136.8
44	64.1	192.3
44.25	48.5	145.5
44.5	53.8	161.4
44.75	44.6	133.8
45	75.6	226.8
45.25	71.9	215.7
45.5	61.5	184.5
45.75	70.4	211.2
46	66	198
46.25	52.1	156.3
46.5	43.3	129.9
46.75	38.9	116.7
47	51.9	155.7
47.25	66.9	200.7
47.5	64.7	194.1
47.75	47.6	142.8
48	41.8	125.4
48.25	38	114
48.5	34.6	103.8
48.75	34.7	104.1
49	34.9	104.7
49.25	29.2	87.6
49.5	33.7	101.1
49.75	49.5	148.5
50	67.8	203.4
50.25	64.1	192.3
50.5	72.2	216.6
50.75	58.1	174.3
51	56.2	168.6
51.25	68	204
51.5	63.1	189.3
51.75	75.3	225.9
52	68.4	205.2
52.25	71.1	213.3
52.5	64.8	194.4
52.75	73.1	219.3
53	60.3	180.9
53.25	65.1	195.3
53.5	65.4	196.2
53.75	71	213
54	59.1	177.3
54.25	51.8	155.4
54.5	52.2	156.6
54.75	63.1	189.3
55	53.3	159.9
55.25	53.6	160.8
55.5	50.4	151.2
55.75	57.6	172.8
56	58.3	174.9
56.25	48.3	144.9
56.5	51.4	154.2
56.75	49.9	149.7
57	61.4	184.2
57.25	46.5	139.5
57.5	53.1	159.3
57.75	60.3	180.9
58	69.8	209.4
58.25	65.3	195.9
58.5	58.3	174.9
58.75	66.7	200.1
59	53.6	160.8
59.25	65	195
59.5	50.4	151.2
59.75	49.7	149.1
60	41.8	125.4
60.25	51.1	153.3
60.5	44.1	132.3

60.75	53.6	160.8	75.5	39	11
61	52.7	158.1	75.75	33.1	99.
61.25	48.5	145.5	76	29.1	87.
61.5	52.1	156.3	76.25	25.4	76.
61.75	51.4	154.2	76.5	26.6	79
62	48.5	145.5	76.75	24	7
62.25	61.5	184.5	77	21.2	63
62.5	53.5	160.5	77.25	18.6	55
62.75	51.3	153.9	77.5	19.7	59
63	44.7	134.1	77.75	32.6	97.
63.25	39.9	119.7	78	36.9	110.
63.5	49.2	147.6	78.25	40.8	122.
63.75	52.6	157.8	78.5	47.6	142
64	51.9	155.7	78.75	44.5	133
64.25	61.2	183.6	79	39.3	117
64.5	58.3	174.9	79.25	55.1	165
64.75	59.7	179.1	79.5	67.6	202
65	46.6	139.8	79.75	61.7	185.1
65.25	41.6	124.8	80	55.4	166.
65.5	42.9	128.7	80.25	55.9	167.
65.75	66	198	80.5	48.9	146.
66	65.9	197.7	80.75	45.2	135
66.25	69.7	209.1	81	53.1	159.
66.5	62.2	186.6	81.25	59.1	177.
66.75	44.5	133.5	81.5	51.4	154.
67	44.9	134.7	81.75	68.3	204
67.25	47.4	142.2	82	65.6	196
67.5	52.3	156.9	82.25	66.4	199.
67.75	55.6	166.8	82.5	68.4	205.
68	75.2	225.6	82.75	77.8	233.
68.25	66.6	199.8	83	77.3	231
68.5	52.6	157.8	83.25	68.5	205.
68.75	49.5	148.5	83.5	67.1	201.
69	67.9	203.7	83.75	48.4	145.
69.25	52.8	158.4	84	48.9	146.
69.5	59.8	179.4	84.25	65.1	195.
69.75	56.1	168.3	84.5	70.5	211.
70	52.7	158.1	84.75	71.4	214.
70.25	62	186	85	51.8	155
70.5	48.3	144.9	85.25	58.2	174
70.75	56	168	85.5	61.8	185
71	50.1	150.3	85.75	66.7	200.1
71.25	62.4	187.2	86	72.7	218.1
71.5	62.1	186.3	86.25	61.4	184.
71.75	51.5	154.5	86.5	48.3	144
72	59.4	178.2	86.75	49.3	147
72.25	61.3	183.9	87	56.3	168
72.5	58.1	174.3	87.25	60.5	181
72.75	64.8	194.4	87.5	59.3	177
73	54.6	163.8	87.75	70.8	212.
73.25	59.4	178.2	88	66.7	200.1
73.5	58.6	175.8	88.25	66.5	199.
73.75	63.8	191.4	88.5	63.2	189
74	52.3	156.9	88.75	58.7	176.1
74.25	50.7	152.1	89	45.6	136
74.5	55.3	165.9	89.25	38.5	115
74.75	51.7	155.1	89.5	43.2	129
75	46.3	138.9	89.75	49.3	147
75.25	45.3	135.9	90	66.9	200.

90.25	63.6	190.8	105	52.4	157.2
90.5	69.1	207.3	105.25	46.3	138.9
90.75	53.7	161.1	105.5	43.2	129.6
91	48.3	144.9	105.75	41.8	125.4
91.25	40	120	106	35.4	106.2
91.5	34.3	102.9	106.25	29.4	88.2
91.75	31.6	94.8	106.5	29.3	87.9
92	31.8	95.4	106.75	31.4	94.2
92.25	26.9	80.7	107	34.5	103.5
92.5	26.3	78.9	107.25	46.9	140.7
92.75	26.3	78.9	107.5	41.8	125.4
93	22.7	68.1	107.75	41.9	125.7
93.25	26.8	80.4	108	43.2	129.6
93.5	23.4	70.2	108.25	38.2	114.6
93.75	20.4	61.2	108.5	40.8	122.4
94	37.6	112.8	108.75	45.5	136.5
94.25	44.6	133.8	109	44.5	133.5
94.5	41.7	125.1	109.25	44.9	134.7
94.75	42.5	127.5	109.5	48.1	144.3
95	40	120	109.75	51.8	155.4
95.25	62.7	188.1	110	59.7	179.1
95.5	45	135	110.25	52.9	158.7
95.75	77.2	231.6	110.5	41.9	125.7
96	61.5	184.5	110.75	57.5	172.5
96.25	72.8	218.4	111	56.4	169.2
96.5	65.6	196.8	111.25	51.8	155.4
96.75	70.5	211.5	111.5	45.1	135.3
97	60.9	182.7	111.75	64.1	192.3
97.25	58.5	175.5	112	71.5	214.5
97.5	53.2	159.6	112.25	65.3	195.9
97.75	55.4	166.2	112.5	64	192
98	59.2	177.6	112.75	58.7	176.1
98.25	59	177	113	54.1	162.3
98.5	57	171	113.25	52.2	156.6
98.75	52.3	156.9	113.5	56.7	170.1
99	58.8	176.4	113.75	49	147
99.25	58.5	175.5	114	49.3	147.9
99.5	66.9	200.7	114.25	42.7	128.1
99.75	62.9	188.7	114.5	41.6	124.8
100	62.3	186.9	114.75	42.1	126.3
100.25	69.6	208.8	115	44.6	133.8
100.5	61.2	183.6	115.25	42.3	126.9
100.75	61.9	185.7	115.5	60.9	182.7
101	51.9	155.7	115.75	62.2	186.6
101.25	48.7	146.1	116	52.4	157.2
101.5	58.5	175.5	116.25	51.7	155.1
101.75	58.2	174.6	116.5	53.3	159.9
102	61.6	184.8	116.75	60.9	182.7
102.25	57.2	171.6	117	48.2	144.6
102.5	56.6	169.8	117.25	48.4	145.2
102.75	48.6	145.8	117.5	43.8	131.4
103	47.8	143.4	117.75	42.3	126.9
103.25	52.8	158.4	118	40.3	120.9
103.5	53.4	160.2	118.25	38.3	114.9
103.75	54.7	164.1	118.5	45.3	135.9
104	59.8	179.4	118.75	54.8	164.4
104.25	61.3	183.9	119	48.5	145.5
104.5	64	192	119.25	44.6	133.8
104.75	60.9	182.7	119.5	46.4	139.2

119.75	40.3	120.9
120	44.6	133.8
120.25	44.3	132.9
120.5	60.9	293.7
121	58.1	174.3
121.25	61.6	184.8
121.5	46.9	140.7
121.75	39.3	117.9
122	39.4	118.2
122.25	39.8	119.4
122.5	40.5	121.5
122.75	48.8	146.4
123	48.9	146.7
123.25	44.1	132.3
123.5	48.8	146.4
123.75	46.1	138.3
124	42.8	128.4
124.25	36	108
124.5	39	117
124.75	46.4	139.2
125	29.8	89.4
125.25	30.7	92.1
125.5	29.6	88.8
125.75	28.1	84.3
126	25.2	75.6
126.25	24.3	72.9
Average=	49.5	148.5

Check span gases- 67.5%
Check zero gases- 1.6%